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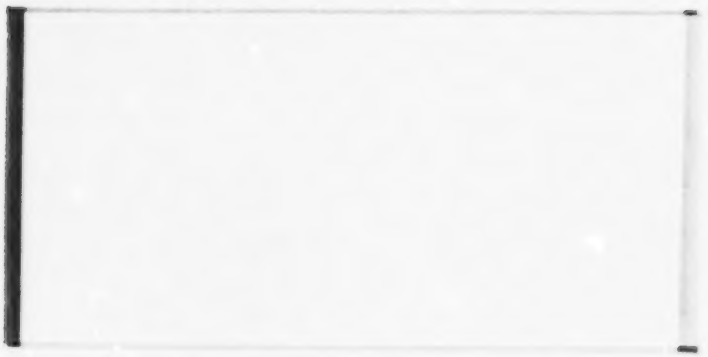

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PARTITIONING OF GAMMA-EMITTING RADIONUCLIDES BETWEEN WATER AND LAKE ONTARIO SEDIMENTS

Report No 86-261-K
David W. Rodgers
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

^{60}Co and ^{137}Cs adsorption distribution coefficients (Kd's) varied by more than an order of magnitude among sediment samples collected from the nearshore zone of Lake Ontario near Pickering NGS and from deeper basins within the lake. Kd's of both radionuclides were highly correlated, with ^{137}Cs Kd's approximately 10-20 times greater than ^{60}Co Kd's. In addition, similar variables, particularly particle size, cation exchange capacity and sediment ^{60}Co activity, were significant in regression equations predicting both ^{60}Co and ^{137}Cs Kd's. Thus, similar factors are likely to determine the adsorption characteristics of both ^{60}Co and ^{137}Cs. Sediment ^{60}Co activity was strongly correlated with the Kd's of both ^{60}Co and ^{137}Cs, and was a significant parameter in regression equations predicting Kd's of both radionuclides. Sediment ^{137}Cs activity was not significantly correlated with either Kd, however, and was a significant parameter only in regression equations predicting the ^{137}Cs Kd. These differences in the relationships of Kd's with sediment ^{60}Co and ^{137}Cs activities indicate that additional factors are also important to the determination of sediment radionuclide activity.

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34-519-090	837.88	November 17, 1986	86-261-K

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EXECUTIVE SUMMARY

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David W. Rodgers
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Ontario Hydro Nuclear Generating Stations (NGS) produce a variety of gamma-emitting radionuclides in the course of their operations. Although the quantities of radionuclides released are generally less than 1% of the Derived Emission Limit of each NGS, some of these radionuclides have long half-lives and could potentially accumulate in the aquatic environment. Many of the gamma-emitting radionuclides released to the aquatic environment have a high affinity for suspended particles, which may then settle to the sediments. Gamma-emitting radionuclides may thus accumulate in the sediments, which serve as a sink for these radionuclides in aquatic ecosystems.

This study investigated the relationships between the distribution of gamma-emitting radionuclides in Lake Ontario sediments, as determined in an earlier survey (OHRDR 85-3-K), and the affinity of these sediments for ^{60}Co and ^{137}Cs, two of the principal gamma-emitting radionuclides released by CANDU reactors. The affinity of the sediments for ^{60}Co and ^{137}Cs was measured by determining the adsorption distribution coefficient (Kd) of each sediment. Sediment Kd's were calculated from the quantity of radionuclide which remained in solution after mixing the sediment (1 g) and water (10 ml) with a trace quantity of ^{60}Co or ^{137}Cs, for 24 h.

Kd's of both radionuclides were highly correlated, with ^{137}Cs Kd's approximately ten to twenty times greater than ^{60}Co Kd's. In addition, similar variables, particularly particle size, cation exchange capacity and sediment ^{60}Co activity, were significant in regression equations predicting both ^{60}Co and ^{137}Cs Kd's. Thus, similar factors are likely to determine the adsorption characteristics of both ^{60}Co and ^{137}Cs.

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Sediment ^{60}Co activity was strongly correlated with the Kd's of both ^{60}Co and ^{137}Cs, and was a significant parameter in regression equations predicting Kd's of both radionuclides. Sediment ^{137}Cs activity was not significantly correlated with either Kd, however, and was a significant parameter only in regression equations predicting the ^{137}Cs Kd. These differences in the relationships of Kd's with sediment ^{60}Co and ^{137}Cs activity indicate that additional factors are also important to the determination of sediment radionuclide activity.

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To: Dr. D. Mills
Director of Research

PARTITIONING OF GAMMA-EMITTING RADIONUCLIDES BETWEEN WATER AND LAKE ONTARIO SEDIMENTS

INTRODUCTION

Ontario Hydro Nuclear Generating Stations (NGS) produce a variety of gamma-emitting radionuclides, either as fission products (ie, ^{137}Cs and ^{134}Cs) or through neutron activation of stable system components (ie, ^{65}Zn and ^{60}Co). Although the quantities of radionuclides released are generally less than 1% of the Derived Emission Limit of each NGS, some of these radionuclides have long half-lives and could potentially accumulate in the aquatic environment.

Many of the gamma-emitting radionuclides released to the aquatic environment have a high affinity for suspended particles, which will eventually settle to the sediments. Many gamma-emitting radionuclides will thus tend to accumulate in the sediments, which serve as a sink for these radionuclides in aquatic environments. Accordingly, the behavior of many gamma-emitting radionuclides in aquatic ecosystems may be dominated by exchange between water and sediments (Lerman and Taniguchi 1973; OHRDR 82-271-K). In models of the environmental dynamics of a number of these radionuclides, exchange of radionuclide between sediment and water significantly affected both the predicted distribution of the radionuclide and the corresponding dose estimates (Booth 1975).

This study investigated the relationships between the distribution of gamma-emitting radionuclides in Lake Ontario sediments, as determined in an earlier survey (OHRDR 85-3-K), and the affinity of these sediments for ^{60}Co and ^{137}Cs, two of the principal gamma-emitting radionuclides released by CANDU reactors. The affinity of the sediments for each radionuclide was measured by determining the adsorption distribution coefficient (Kd) of the sediment. Sediment Kd's were calculated from the quantity of radionuclide which remained in solution after mixing the sediment, water and a trace quantity of ^{60}Co or ^{137}Cs, for 24 h, and provide a standard index of the relative affinity of the radionuclide for sediments and water under defined experimental conditions. The relationships of the adsorption distribution

coefficients to measured physical and chemical properties of the sediments, and the ^{60}Co and ^{137}Cs activities of the sediments were then examined.

MATERIALS AND METHODS

The Lake Ontario sediment samples used in this study included both shallow, nearshore samples, collected in the vicinity of Pickering NGS and deeper, offshore samples collected from some of the deeper basins in the lake. The majority of sediments were selected from samples collected in an earlier systematic survey of the distribution of gamma-emitting radionuclides of Lake Ontario sediments (OHRDR 85-3-K), at sites shown in Figure 1. Briefly, samples were collected by ponar grab at the 3, 6, 12 and 20 m depth contours on a series of transects perpendicular to the Lake Ontario shoreline (Figure 1a). Transect 3 was located directly offshore of Pickering NGS, while transects 4 and 7 were, respectively, 2 and 8 km east of Pickering NGS. As the prevailing longshore currents in the vicinity of Pickering NGS are west to east (OHRDR 85-3-K), the latter transects should be representative of sediments 'downstream' of Pickering NGS. A sample of the organic sediment found at the mouths of streams flowing into Lake Ontario was collected by ponar grab from near the outfall of Pickering Creek in Frenchman's Bay, west of Pickering NGS. Samples from deeper basins were collected by Dr. R.L. Thomas (Canada Center for Inland Waters, Burlington, Ontario), from depths of 115 m in the Niagara Basin (Figure 1b) and 218 m in the Rochester Basin of Lake Ontario (OHRDR 85-3-K). The suspended solids contained within the Pickering intake water were sampled directly by collecting material which settled into a plastic pail with a perforated lid (3-5 mm holes) which was suspended in the intake channel of Pickering NGS from July - September, 1984.

Sediments were air dried at 60° C, passed through a 2 mm sieve, then dried again to constant weight (60° C), and stored in closed plastic containers until further analysis. The wet sieve method (Folk 1968) was used to characterize the particle size distribution of the sediments, while organic content was determined gravimetrically after combustion at 550°C to constant weight. Cation exchange capacity of the samples was determined by the Soils Analysis Laboratory of the University of Guelph using a 'summation' method, with barium chloride used as the displacement salt (Rhoades 1982). The physical and chemical characteristics measured in the sediment samples used in this study are summarized in Table 1.

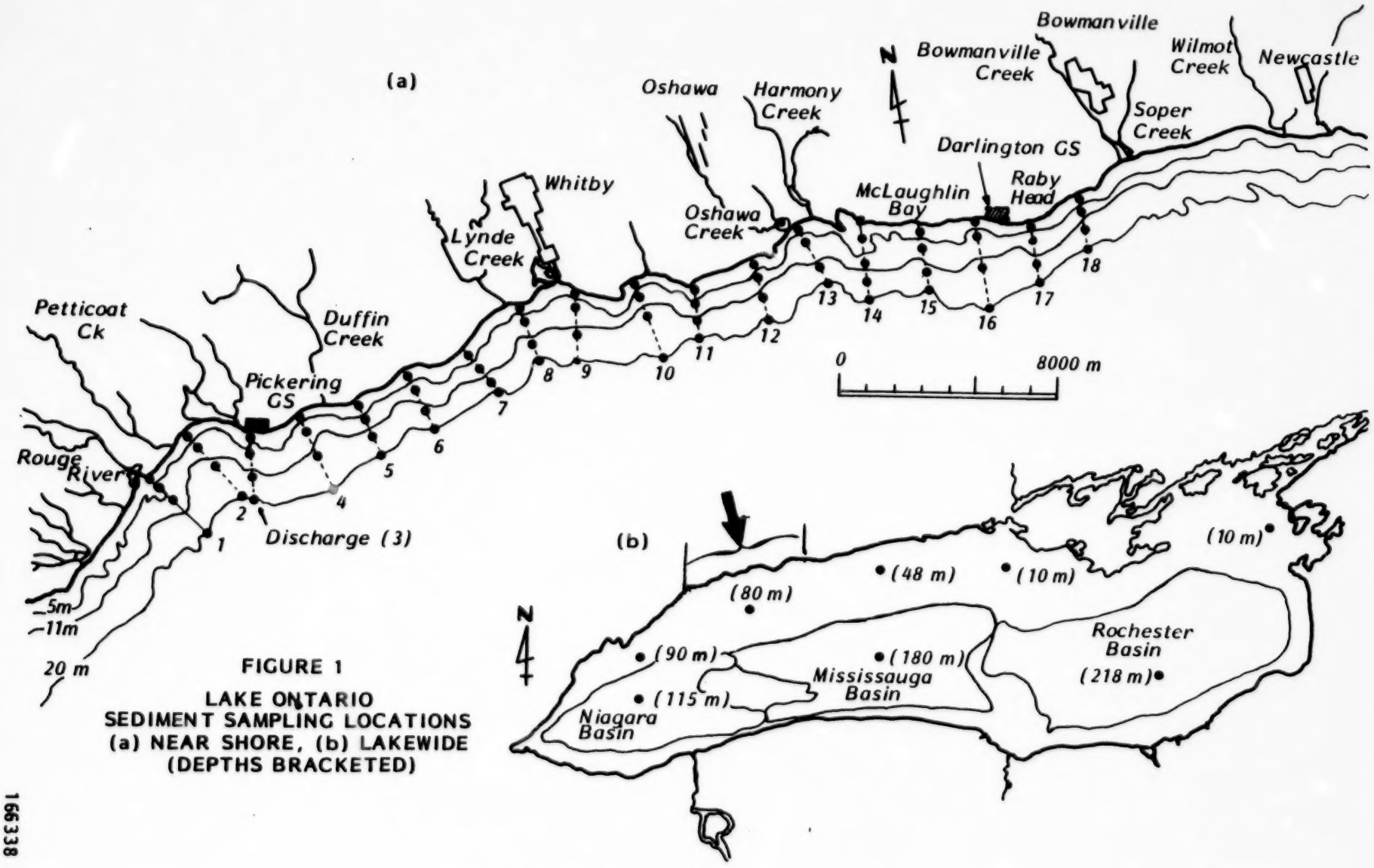

FIGURE 1

LAKE ONTARIO
SEDIMENT SAMPLING LOCATIONS
(a) NEAR SHORE, (b) LAKEWIDE
(DEPTHS BRACKETED)

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Table 1 : Physical and chemical properties of the Lake Ontario sediments used in the determination of radionuclide distribution coefficients.

Sample Location	Depth (m)	Organic Content (%)	Particle Size (ϕ)	Cation Exchange Capacity (mEq/100g)	^{60}Co Activity (Bq/kg)	^{137}Cs Activity (Bq/kg)
Pickering Intake	1	6.16	3.422	58.7	---	---
Frenchman's Bay	1	12.0	3.180	62.3	---	---
Transect 3 - 3 m	3	2.96	2.706	120.3	250	410
Transect 3 - 6 m	6	2.45	2.741	58.7	52	200
Transect 3 - 12 m	12	2.75	2.835	58.3	72	330
Transect 4 - 3 m	3	1.99	0.372	60.1	34	240
Transect 4 - 6 m	6	0.57	2.145	22.1	nd	30
Transect 4 - 12 m	12	0.59	1.485	18.0	nd	130
Transect 7 - 6 m	6	1.33	0.905	22.1	nd	170
Transect 7 - 12 m	12	0.59	0.145	20.3	nd	550
Transect 7 - 20 m	20	0.47	1.099	32.1	nd	980
Niagara Basin	115	11.7	3.595	48.9	33	9700
Rochester Basin	218	11.5	3.350	32.1	690	7900

$\phi = -\log_2$ diameter (mm)

nd - not detected, detection limit < 1 Bq/kg

The ^{60}Co and ^{137}Cs adsorption distribution coefficients of the sediments were determined using batch methods. Approximately 1 g of dry sediment was weighed into a 50 mL 'Oak Ridge' type polycarbonate centrifuge tube (Nalgene, Rochester, N.Y.), then water (9.8 mL) and the radiolabeled cesium or cobalt chloride solution (0.2 mL - approximately 3.7 kBq) were added. The sediment-water mixture was agitated on a rotary shaker for 24 h to ensure equilibration (Gillham et al. 1980; Stanners and Aston 1981) and then centrifuged for 30 min at 15,000 rpm ($r_{(max)}$ = 27 000 x g). The pH of the resulting supernatant was consistently in the range of 6.0 $\pm$ 0.3. Duplicate aliquots (2.5 mL) of the supernatant were added to Monophase 40+ scintillation fluid (15 mL - Packard Instruments, Mississauga, Ont.) and activity determined by liquid scintillation counting (Packard Tri-Carb Model 300 Scintillation Counter), with results corrected for counting efficiency and quench. At least two determinations were made with each sediment sample. To correct for adsorption of the radionuclide to the centrifuge tube, three control tubes were processed as above but without added sediments, during each determination of distribution coefficients. Dechlorinated Toronto tap water, which is drawn from Lake Ontario and is thus representative of Lake Ontario water at Pickering NGS, was used in the majority of tests. Additional tests, to evaluate the effects of the ionic content of test water on distribution coefficient, were conducted using deionized water rather than tap water.

The radionuclides, $^{60}CoCl_2$ and $^{137}CsCl$ (37 MBq in 0.5 M HCl; ^{60}Co > 2.8 GBQ/mgCo; ^{137}Cs carrier-free), were purchased from New England Nuclear, Lachine, Que. The radionuclide solutions were diluted, on receipt, with 0.5 M HCl to 1 L and stored in polyethylene bottles. Working solutions of radionuclides were prepared by further dilution of the above solution (1:1) with 0.5 M HCl, thus approximately 220 000 dpm of radionuclide were added to each sample. Addition of the radionuclide solution added less than 14 ng of Co or Cs to the sample, resulting in metal concentrations of less than 0.14 µg/L. The scintillation counter was calibrated using certified standards of ^{60}Co and ^{137}Cs (New England Nuclear, Lachine, Que.) for aqueous samples of up to 5 mL in Monophase 40+ (OHRDR CN84-1451-K).

The adsorption distribution coefficient (Kd) of each sample was calculated according to the equation:

$$Kd = ((Ac - As)/ As) * (V/m)$$

where

V = volume of the solution (mL),

m = mass of sediment (g),

Ac = activity (dpm/mL) of supernatant in control tube without sediment, and

As = activity (dpm/mL) of supernatant in experimental tube with sediment added.

Results were analyzed using appropriate analysis of variance and regression models (Steel and Torrie 1980; Draper and Smith 1981). A logarithmic transformation was used in the analysis of variance, as residual plots indicated that this transformation was required to comply with statistical assumptions of normality and equality of variance. If the F ratio in the analysis of variance was significant ($P < 0.05$), cell means were compared using the least significant difference (LSD) method. The 95% significance level ($P < 0.05$) was employed as the criterion of decision in all statistical comparisons. 'Best' multiple regression equations were selected on the basis of residual plots, adjusted R^2 and Cp statistic (Draper and Smith 1981).

RESULTS

Adsorption distribution coefficients of both ^{60}Co and ^{137}Cs varied by more than an order of magnitude among sediment samples (Table 2). Distribution coefficients of ^{60}Co ranged from 33 (Rochester Basin - 218 m) to 982 (Transect 3 - 3 m), while distribution coefficients of ^{137}Cs varied from 661 (Transect 7 - 20 m) to 11 737 (Transect 3 - 3 m). The relative order of distribution coefficients was generally similar for both ^{60}Co and ^{137}Cs, with the highest distribution coefficients obtained with sediment from Transect 3 - 3 m, followed by sediments from Transect 7 - 12 m (Table 2). The distribution coefficients measured for the suspended solids collected in the intake of Pickering NGS were intermediate relative to other values. In general, distribution coefficients determined using dechlorinated Toronto tap water were similar to those obtained using distilled water (Table 2), and the differences between these values were not statistically significant.

The distribution coefficients of ^{60}Co and ^{137}Cs were highly correlated (Pearson correlation coefficient r=0.95) with ^{137}Cs distribution coefficients roughly ten to twenty times greater than the corresponding values determined for ^{60}Co. For both

Table 2: Distribution coefficients of ^{60}Co and ^{137}Cs for Lake Ontario sediments with deionized and dechlorinated Toronto waters (Mean ± SE with n in parentheses, within each radionuclide and water category, means with similar superscripts do not differ significantly ($p<.05$)).

Sample Location	^{60}Co		^{137}Cs	
	Toronto Tap Water	Deionized Water	Toronto Tap Water	Deionized Water
Pickering Intake	$69.3 \pm 1.9^{e,f}$ (8)	74.0 ± 3.1^{d} (3)	$2310 \pm 140^{d,e}$ (7)	2440 ± 70^{b} (3)
Frenchman's Bay	176 ± 27^{c} (7)	148 ± 2^{c} (3)	2890 ± 301^{d} (6)	2330 ± 380^{b} (3)
Transect 3 - 3 m	982 ± 38^{a} (6)	1100 ± 25^{a} (3)	11700 ± 1400^{a} (5)	10800 ± 500^{a} (3)
Transect 3 - 6 m	139 ± 6^{c} (7)	144 ± 3^{c} (3)	1200 ± 40^{f} (4)	995 ± 36^{c} (3)
Transect 3 - 12 m	131 ± 7^{c} (6)	137 ± 4^{c} (3)	1250 ± 120^{f} (4)	1080 ± 20^{c} (3)
Transect 4 - 3 m	$147 \pm 41^{c,d}$ (6)	306 ± 44^{b} (3)	4640 ± 700^{c} (5)	3110 ± 490^{b} (3)
Transect 4 - 6 m	$54.0 \pm 10.2^{f,g}$ (5)	65.0 ± 2.0^{d} (2)	$952 \pm 147^{f,g}$ (6)	1080 ± 2^{c} (2)
Transect 4 - 12 m	$51.2 \pm 12.9^{f,g}$ (5)	44.0 ± 4.0^{e} (2)	1920 ± 120^{e} (3)	1160 ± 250^{c} (3)
Transect 7 - 6 m	$75.0 \pm 4.0^{d,e}$ (3)	---	977 ± 69^{f} (3)	---
Transect 7 - 12 m	398 ± 37^{b} (3)	---	7370 ± 170^{b} (3)	---
Transect 7 - 20 m	$48.7 \pm 12.3^{f,g}$ (3)	---	661 ± 44^{g} (3)	---
Niagara Basin	$45.7 \pm 0.3^{f,g}$ (3)	---	$2640 \pm 40^{d,e}$ (3)	---
Rochester Basin	33.0 ± 0^{g} (3)	---	$2370 \pm 130^{d,e}$ (3)	---

radionuclides, distribution coefficients were also significantly correlated with the sediment ^{60}Co activity (r=0.73 for Kd(Co) and r=0.83 for Kd(Cs)) and cation exchange capacity (r=0.64 for Kd(Co) and r=0.74 for Kd(Cs)). The Pearson correlation coefficients between distribution coefficients and other variables, including organic content, particle size, location and depth of sampling, were not statistically significant. Sediment ^{60}Co activity was significantly correlated with cation exchange capacity (r=0.90), while sediment ^{137}Cs activity was significantly correlated with organic content (r=0.96), depth (r=0.89) and particle size (r=0.61).

The relationships of distribution coefficients to other parameters were examined further using multiple regression techniques. The distribution coefficients for ^{60}Co or ^{137}Cs (Kd(Co) and Kd(Cs), respectively) were the dependent variables in the regression equations, while independent variables included the corresponding distribution coefficient, the activities of ^{60}Co and ^{137}Cs in the sediments (Co and Cs, respectively), the mean particle size (PS), the mean organic content (OC) and the depth (DP) at which the sediment sample was collected. As significant collinearity problems arose when the corresponding distribution coefficient and the sediment ^{60}Co and ^{137}Cs activities were included as independent variables in the same equation, separate regression equations were calculated for the various combinations of independent variables.

When the corresponding distribution coefficient was included as an independent variable in the regression equation and the sediment ^{60}Co and ^{137}Cs activities omitted, the important variables for predicting either cesium or cobalt distribution coefficients were the corresponding distribution coefficient, particle size and organic content. The 'best' equations for each distribution coefficient were:

$$Kd(Co) = 0.07865\ Kd(Cs) + 73.00\ PS - 20.52\ OC - 137.1 \quad (n = 13,\ \text{multiple } R^2(adj) = 0.92) \quad (1)$$

and

$$Kd(Cs) = 1888 + 11.87\ Kd(Co) + 247.9\ OC - 899.6\ PS \quad (n = 13,\ \text{multiple } R^2(adj) = 0.91). \quad (2)$$

When the activities of ^{60}Co and ^{137}Cs in the sediments were included in the regression equation and the corresponding distribution coefficient omitted from the independent variables, particle size and sediment ^{60}Co activity were the significant

variables in predicting the cobalt distribution coefficient. The above variables and sediment ^{137}Cs activity were important for the prediction of the cesium distribution coefficient. The equations which best described the relations of these terms to each distribution coefficient were:

$$Kd(Co) = 214.9 - 108.2\ PS + 4.020\ Co \quad (n = 11,\ \text{multiple } R^2(adj) = 0.84) \tag{3}$$

and

$$Kd(Cs) = 4732 - 2364\ PS + 51.20\ Co + 0.3901\ Cs \quad (n = 11,\ \text{multiple } R^2(adj) = 0.76). \tag{4}$$

If sediment ^{60}Co and ^{137}Cs activities and the corresponding distribution coefficients were excluded as independent variables, particle size and cation exchange capacity emerged as the important variables in predicting the ^{60}Co distribution coefficient. The same variables and sampling depth were significant to the prediction of the ^{137}Cs distribution coefficient. The 'best' equations for predicting the distribution coefficients were:

$$Kd(Co) = 8.759\ CEC - 67.88\ PS - 100.2 \quad (n = 13,\ \text{multiple } R^2(adj) = 0.74) \tag{5}$$

and

$$Kd(Cs) = 51.25 + 16.31\ DP - 1463\ PS + 117.4\ CEC \quad (n = 13,\ \text{multiple } R^2(adj) = 0.77). \tag{6}$$

DISCUSSION

Among the Lake Ontario sediments sampled, ^{60}Co and ^{137}Cs adsorption distribution coefficients each varied by more than an order of magnitude. A similar wide range in values of ^{60}Co and ^{137}Cs distribution coefficients has been observed among sediments from different locations in a number of other studies (Duursma and Bosch 1970; Duursma and Eisma 1973; Schell et al. 1980), however, and the present values are within the range of values encompassed by these previous reports.

In the present study, ^{60}Co and ^{137}Cs adsorption distribution coefficients were highly correlated, with ^{137}Cs distribution coefficients roughly ten to twenty times greater than the corresponding values determined for ^{60}Co. In contrast, the ^{60}Co distribution coefficients reported in earlier studies were generally greater than the corresponding ^{137}Cs distribution coefficients for the same sediments. However, many of these

studies used marine sediments and seawater in the determination of adsorption distribution coefficients, and the K^+ ion in marine systems may significantly reduce ^{137}Cs distribution coefficients (Cheng and Hamaguchi 1968; Stanners and Aston 1981). Even among freshwater sediments, the relative ordering of ^{60}Co and ^{137}Cs adsorption distribution coefficients may vary among sediments. For example, the ^{60}Co adsorption coefficients of Clinch River sediments and Lake Washington sediments were approximately 10^2 and 10^4, respectively, yet the ^{137}Cs adsorption distribution coefficients of both sediments were approximately 10^3 (Schell et al. 1980). As a number of factors specific to each study including sediment collection and storage procedures, sediment/water ratios and test conditions may significantly affect adsorption distribution coefficients (Duursma and Bosch 1970; Schell et al. 1980), comparisons among studies should emphasize relative trends rather than absolute values.

Adsorption distribution coefficients of both ^{60}Co and ^{137}Cs were also significantly correlated with the cation exchange capacity and the sediment ^{60}Co activities of the sediment samples. Further, these same variables were consistently selected in multiple regression equations relating adsorption distribution coefficients to other variables, with particle size and sediment ^{137}Cs activity also significant in some equations. As ^{60}Co and ^{137}Cs adsorption distribution coefficients were strongly correlated, and a similar subset of variables was selected in regression equations predicting both distribution coefficients, similar factors are likely to determine the adsorption characteristics of both radionuclides.

The strong positive relationship between cation exchange capacity and adsorption distribution coefficients indicates that cation exchange may be critical to the adsorption of both ^{60}Co and ^{137}Cs. This relationship is consistent with earlier studies (Cheng and Hamaguchi 1968; Duursma and Eisma 1973; Stanners and Aston 1981). The ionic concentrations of Lake Ontario water did not affect radionuclide adsorption, as adsorption distribution coefficients determined with deionized water were not significantly different from those determined with Toronto tap water. In marine and groundwater systems, however, ionic concentrations may significantly affect radionuclide distribution coefficients. In marine sediments, K^+ ions significantly affect adsorption of radiocesium (Stanners and Aston 1981); while ^{137}Cs adsorption distribution coefficients of Canadian unconsolidated geologic materials were strongly influenced by the natural exchangeable cesium content of the material (Gillham et al 1980).

Adsorption distribution coefficients may also be affected by pH. For Clinch River sediment samples, ^{60}Co distribution coefficients increased from approximately 10^3 at pH 6 to greater than 10^5 at pH greater than 8, while ^{137}Cs distribution coefficients were

relatively constant from pH 4 - 10 (Schell et al. 1980).. Accordingly, in Lake Ontario with surface water pH in the range of 7.8-8.3 (OHRDR 83-193-K) and sediment pH in the range of 6.7 - 7.5 (Kemp and Thomas 1976), cobalt absorption distribution coefficients would be expected to be higher than those measured in the present study at pH 6.0.

Although mean particle size was not directly correlated with adsorption distribution coefficients, it was a significant variable in regression equations predicting both ^{60}Co and ^{137}Cs distribution coefficients. The inverse relationship between adsorption distribution coefficients and mean particle size was also observed in previous studies elsewhere (Nagaya and Nakamura 1975; Aston and Stanners 1982). The increase in adsorption capacity with decreasing particle size likely results from the increased available surface area of an equivalent weight of smaller particles. In addition, the proportion of clay materials in the sediment generally increases with decreasing particle size and adsorption processes will shift from physical adsorption to ion exchange (Charles and Prime 1983).

Organic content was less critical to the prediction of adsorption distribution coefficients for the sediment samples used in the present study, and was an important variable only in Equations 1 and 2, where the other distribution coefficient was included in the regression equation and the sediment ^{60}Co and ^{137}Cs activities were excluded. Although organic content of sediments has been reported to significantly affect the distribution of ^{60}Co and ^{137}Cs in surveys of environmental sediments (Revsin et al. 1984; OHRDR 85-3-K), the effects of organic content on adsorption distribution coefficients reported in previous laboratory studies have varied. Gillham et al. (1980) noted that organic content had no apparent effect on ^{137}Cs adsorption distribution coefficients of unconsolidated Canadian geologic material. Duursma and Eisma (1973) observed an increase in the ^{60}Co and ^{137}Cs distribution coefficients of marine sediments at higher concentrations of organic material, but attributed the elevation of distribution coefficients to a coincident rise in the base exchange capacity of the sediments. The addition of organic ligands to the sediment-water mixture significantly affected ^{60}Co distribution coefficients but had little effect on ^{137}Cs distribution coefficients (Schell et al. 1980).

Sediment ^{60}Co activity correlated significantly with both ^{60}Co and ^{137}Cs adsorption distribution coefficients and was significant in regression equations predicting both ^{60}Co and ^{137}Cs adsorption distribution coefficients. Sediment ^{137}Cs activity was not significantly correlated with either adsorption distribution coefficient, but was significant in regression equations predicting ^{137}Cs adsorption distribution coefficients. These differences in the significance of sediment ^{60}Co and ^{137}Cs

activities to the prediction of adsorption distribution coefficients likely reflect differences in the physical and chemical adsorption characteristics of the radionuclides, but may also result from differences in the origin of these radionuclides. Because of the long half-life of ^{137}Cs (30.2 y), atmospheric fallout from weapons testing remains a major source of this radionuclide and the sources of this radionuclide to Lake Ontario are thus diffuse. The half-life of ^{60}Co (5.6 y) is much shorter, however, and in the nearshore sediment samples the observed ^{60}Co activity appears to be localized near Pickering NGS (OHRDR 85-3-K). These differences between ^{60}Co and ^{137}Cs also indicate that factors other than adsorption affinity, per se, may be critical to the determination of activities of radionuclides in Lake Ontario sediments. For the full series of Lake Ontario sediment samples collected in the vicinity of Pickering NGS, highest ^{60}Co activities were observed in samples collected near Pickering NGS, while sediment ^{137}Cs activity was positively correlated with organic content of the sediment and depth of collection (OHRDR 85-3-K).

SUMMARY

1. The partitioning between water and sediments of ^{60}Co and ^{137}Cs, two gamma-emitting radionuclides released to the aquatic environment by Ontario Hydro NGS's, was determined using batch techniques. Sediments were collected from the nearshore zone of Lake Ontario near Pickering NGS and from deeper basins within the lake.

2. Adsorption distribution coefficients of both ^{60}Co and ^{137}Cs varied by more than an order of magnitude among sediment samples. The relative order of distribution coefficients was generally similar for both radionuclides. The distribution coefficients of suspended solids collected in the intake of Pickering NGS were intermediate relative to samples from other locations.

3. The adsorption distribution coefficients of ^{60}Co and ^{137}Cs were highly correlated and the same subset of variables (particle size, cation exchange capacity and ^{60}Co activity of the sediments) was significant in regression equations relating adsorption distribution coefficients to other variables. Accordingly, similar factors are likely to determine the adsorption characteristics of both radionuclides.

4. Sediment ^{60}Co activity correlated significantly with both ^{60}Co and ^{137}Cs adsorption distribution coefficients and was significant in regression equations predicting both ^{60}Co and ^{137}Cs adsorption distribution coefficients. Sediment ^{137}Cs activity was not significantly correlated with either

adsorption distribution coefficient, however, and was a significant parameter only in regression equations predicting the ^{137}Cs adsorption distribution coefficient. These differences between radionuclides indicate that additional factors may also be important to the determination of radionuclide activity in Lake Ontario sediments.

ACKNOWLEDGMENTS

The technical assistance of E. Checko, L.P. King, B. Sim and L. Vereecken Sheehan is gratefully acknowledged. Many of the sediment samples used in this study were provided by R.S. McKinley from samples collected for a previous study (OHRDR 85-3-K).

Approved by:

O.A. Kupcis
Manager
Chemical Research Department

Submitted by:

David W. Rodgers
Biologist
Biological Research Section

Reviewed by:

A.E. Christie
Acting Supervising Biologist
Biological Research Section

DWR:jcb

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